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CONTENTS OF VOLUME 28

JANUARY, 1946. NUMBER 1

MARCH, 1946. NUMBER 2

MAY, 1946. NUMBER 3

JULY, 1946. NUMBER 4

A HEALTH SURVEY OF PIPE COVERING OPERATIONS IN CONSTRUCTING NAVAL VESSELS*

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AN INDUSTRIAL health inspection of an important U. S. Navy Contract Yard indicated that dustiness from miscellaneous pipe covering operations was considerable and that a few of the employees had what appeared to be asbestosis. This is a well-known industrial disease caused by only one thing—prolonged breathing of asbestos dust. The clinical manifestations are shortness of breath and an unusual chest picture by X-ray. In industry the disease is often disabling, but it is much less frequent than silicosis, with which it very properly is classed.

It was not felt that experience in a single yard was enough to justify any general statements on working conditions in other yards, and certainly was no cause for alarm, but the results warranted check-ups elsewhere. Accordingly, arrangements were made to examine by chest X-ray the pipe coverers in two Government Navy Yards, A and B, and in two Navy Contract Yards, C and D. Examinations were made of the working conditions including dust counts of the air breathed with microscopic and chemical analysis of the dust itself.

We would point out that this procedure is customary in making such surveys of occupational diseases—medical examination of the workers and a study of the nature and concentration of the contaminants in the air breathed.

PIPE COVERING MATERIAL

An important ingredient of pipe covering material used on U. S. Navy vessels is amosite. This mineral is a magnesium iron silicate of variable composition. The name is the generic one for an asbestos type of fibrous mineral mined in South Africa.

The chief reasons for the wide use of amosite felt and pipe covering in naval work are its low thermal conductivity, light weight, strength, and refractoriness. When the felt and pipe covering were first developed, we were still building vessels under the Washington Treaty of Limitations in Tonnage, and every pound saved meant that much more armor, guns or ammunition for a given displacement, to say nothing of more economic operation for the weight involved in insulation.

Amosite pipe covering weighs about 14 pounds per cubic foot, with a temperature limit of 750°F. as compared to magnesia with a weight of 16 pounds per cubic foot, and a temperature limit of 500° F. High temperature amosite pipe covering weighs about 18 pounds per cubic foot as compared to 26 pounds per cubic foot for other high temperature insulations. Because of the lower conductivity and the higher temperature limit of the amosite type, less of it need be used in a combination covering than other types of insulations.

The development of amosite felt started in 1934 when a need existed to secure a thermal insulation lighter in weight and thermally more efficient than the materials (blocks and cement or asbestos blankets) which were then being used on destroyer turbines. The Navy approved the type developed by a manufacturer in September, 1934. Originally amosite was used only for turbine insulation, but it proved so satisfactory that its field of application enlarged to include insulation of valves, fittings, flanges, etc. From the initial destroyer, it has been used on almost all the destroyers built since that time and on all other combat vessels built since before the War.

Pipe covering was a later development in late 1935 and early 1936. Due to the manufacturing problems involved, it took a longer time to evolve into a satisfactory shape, and its first use on naval vessels was in 1937. Since that time its use has spread markedly and it was used on the great majority of naval combat vessels built during World War II.

Water-repellent amosite felt was developed during the early part of 1942, as a replacement for hair felt in the insulation of cold water lines to prevent sweating. Hair felt had the disad-

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vantage of being combustible and as it was organic, when it became wet it moulded or rotted and could harbor vermin. At this time fires on board certain naval vessels convinced the Navy of the desirability of eliminating any combustible material from on board ship. Eventually water-repellent amosite was made in strips of 50 foot lengths and of suitable width to enclose the circumference of the pipe and enclosed in an extremely light-weight muslin to facilitate handling and reduce the dust, which the water-repellent agent accentuated.

I. Description of Operations and Working Environment

Asbestosis results from breathing asbestos fibers of relatively long length, such as 15 to 75 microns. It is not caused by breathing chopped up asbestos fibers of one or two microns (1). Therefore we are concerned with the presence in air of asbestos fibers which can be seen as such under low power of the ordinary microscope.

The clinical picture of asbestosis can easily be complicated by the presence of diatomaceous earth, a form of amorphous silica, which can cause silicosis and is probably a more serious health risk than asbestosis.

Another dust which may be present is magnesia, MgO, which is in very common use as a heat insulator and is harmless.

Therefore our analyses were done to indicate how much fibrous type of asbestos dust was present in the air breathed, how much silica was present (especially as diatomaceous earth), and how much of the harmless ingredients like iron oxide and carbonates.

Pipe covering may be divided into seven different operations as follows:

1. *Laying out and cutting*
2. *Band saw cutting*
3. *Sewing and preparation of boots and jackets*
4. *Cement mixing*
5. *Molding*
6. *Grinding*
7. *Installation on board ship*

1. *Laying out and cutting*

Rolls of the insulating felt are unwrapped and unrolled on a large layout table or on the floor of the shop. This material, with the exception of the type known as water repellent amosite, is then well wetted with a fine water spray. It is marked into measured sections and cut with a rotary electric hand saw. The cut sections are rolled up and either used immediately or stacked in the storeroom.

Usually one to three workers are employed at this operation. During the handling, unwrapping and unrolling of the asbestos, considerable dust arises, but appears to settle readily. A very fine water spray should be used for wetting down the material as a high velocity spray stirs up dust. Once it is wetted the handling and cutting of the material causes little visible dust. All of the four yards surveyed wet down the insulating material described above.

One Navy Yard has an elaborate exhaust system for the layout table. The entire top of this table is covered with small perforations through which the air is exhausted. This table is sufficiently large that no more than two-thirds of the top is ever covered with material and room air is thereby exhausted through the other third. While no velocity or capacity measurements were made on this system, data presented later in the report indicate that this control measure had a marked effect in reducing the dust count.

2. *Band saw cutting*

A standard band saw such as is found in woodworking shops is used to cut insulation blocks and boards into desired shapes. This operation produces large amounts of air-borne dust, most of which settles slowly. Normally there is only one worker on this operation at any one time.

Inasmuch as this is a very dusty operation, the band saw should be enclosed in a room by itself and should be equipped with adequate local exhaust ventilation both above and below the saw table. Because of the mechanical difficulties in locating this exhaust properly, some of the dust will escape into the air and the operator should therefore wear an approved dust respirator.

3. *Sewing and preparation of boots and jackets*

In this operation jacket covers for valves and pipe joints are fabricated. The work consists of cutting asbestos cloth with shears, padding the jackets with insulating material, and sewing with wire or asbestos cord. These operations give rise to only slight amounts of visible dust, and exhaust ventilation and respiratory protection are neither required nor used. There is usually a large number of workers doing this operation in one large room.

4. *Cement mixing*

For protection and to give a neat appearance the insulation on board ship is usually covered with cement containing a high percentage of asbestos fibers. In mixing, the proper amount of water is added to the dry asbestos cement and thoroughly agitated with a hoe. Occasionally small amounts of asbestos cement are mixed in a pail with a trowel. Considerable dust is raised when the asbestos cement is dumped into the mixing trough and during the early stages of mixing. Ordinarily this process is done in a separate room and only one operator is exposed. The dustiness of this operation warrants the use of exhaust ventilation or respiratory protection or both, although neither is generally used.

Petrographic analyses of asbestos cement indicate that the amount of diatomaceous earth may be as high as 87 per cent by count.

5. *Molding*

Molding is the process of building up the insulation to fit odd shapes of boilerwork and piping. A form is made to the exact shape of the part to be insulated. Block insulation is laid on, adjoining sections glued together, exposed surfaces sealed with asbestos cement and the whole mold covered with asbestos cloth. When dry, the molded insulation can be lifted off the form and is ready to be installed on board ship. This operation is usually done in the shop next to the sewing operation. Very little dust is produced from this operation and no special ventilation or respiratory protection is required.

6. *Grinding*

Several shipyards reclaim their scrap pieces of prefabricated sections of insulation by grinding up this material and using it in the asbestos cement, all of which contributes considerable dustiness. Normally this job is done at infrequent intervals and only one or two men are exposed, but the operation should be isolated, general room exhaust supplied and an approved respirator worn by the operator.

7. *Installation of pipe covering on board ship*

There are a number of operations involved in pipe covering on board ship. Insulation felt is wrapped and pounded tightly around large pipes and joints and fastened firmly in place with wire or asbestos cord. Pipes and boilers are covered with prefabricated sections, which necessitates some hand sewing to fit the sections. Ready mixed cement is applied to fill in spaces and give a smoother finish. Some insulation is wrapped with glass cloth or asbestos cloth for greater strength. The only operations that produce much dust are the wrapping and pounding of amosite and the sewing of sections.

Nearly all of the compartments on board ship are involved in this work, although most of it is concentrated in the machinery spaces. Usually the greater number of pipe coverers work on board ship and relatively few men in the shop. The spacing of workers ranges from one or two men doing a small job in a living space to as many as twenty or thirty men working on ten or more jobs in the engine room. Temporary exhaust ventilation is seldom used on board ship for pipe covering and very few of the workers wear respirators.

Because of the varied nature of pipe covering operations in ship compartments, general exhaust ventilation is to be preferred. If the compartment is large, such as the main engine room, five air changes per hour are needed. In small compartments, such as living spaces, ten to fifteen air changes per hour are required.

II. Composition of Materials Used

According to Navy Specification the rovings of asbestos insulating felt (amosite) shall contain not less than 95 per cent asbestos fiber of the following composition:

Silica (SiO_2) per cent minimum	47.5
Iron oxide (Fe_2O_3) per cent maximum	45.0
Magnesium oxide (MgO) per cent minimum	6.0

Typical analysis of the two types of asbestos fibers in general use are tabulated below:

	Chrysotile	*Amosite*
Silica (SiO_2)	39.05%	50.24%
Magnesia (MgO)	40.07%	3.96%
Alumina (Al_2O_3)	3.67%	
Ferric oxide (Fe_2O_3)	2.41%	7.80%
Ferrous oxide (FeO)		32.00%
Sodium oxide (Na_2O)		2.12%
Combined water (N_2O)	14.48%	3.00%

Therefore amosite alone will not comply with Navy Specifications because of the low magnesia content and must be mixed with chrysotile asbestos to equal or exceed the 6.0 per cent minimum value for magnesia. On the other hand, chrysotile cannot be used alone because of its silica content which is below the minimum 47.5 per cent specified by the Navy. The two types

of asbestos fibers must be mixed together in the proper proportions to satisfy the values set for magnesia and silica. The amounts of these materials used to form this mixture therefore would be 6–43 per cent chrysotile asbestos and 94–57 per cent amosite asbestos.

These two fibers differ mainly in their physical characteristics. Chrysotile is capable of being readily separated into very fine fibers with a soft silky feel, whereas amosite is harsher and requires more manipulation to fiberize it. One authority has stated that the chrysotile has the finest individual fibers, and amosite the coarsest. Because of this difference we may suspect a decided decrease in the number of respirable fibers (below 200 microns in length and 5 microns in diameter) whenever amosite is used in preference to chrysotile asbestos.

TABLE 1

Summary of Materials Used at Each Yard per Month

	Navy Yard A	Navy Yard B	Contract Yard C	Contract Yard D
Amosite	58,200 sq. ft.	50,000 sq. ft.	40,000 sq. ft.	6,325 sq. ft.
Amosite (water-repellent)	—	15,000 sq. ft.	—	3,300 sq. ft.
Prefabricated sections (molded and block)	600 sq. ft. 39,900 linear ft.	1,200 sq. ft. 115,000 linear ft.	1,750 sq. ft. 18,800 linear ft.	15,700 linear ft.
Asbestos cloth	76,500 sq. ft.	106,600 sq. ft.	34,700 sq. ft.	40,000 sq. ft.
Metallic twine Asbestos yarn	—	150 lb.	—	—
Asbestos paper	—	5,500 sq. ft.	4,000 sq. ft.	5,500 sq. ft.
Asbestos board	2,700 linear ft.	6,000 sq. ft.	150 sq. ft.	—
Asbestos cement	34,400 lb.	15,000 lb.	57,500 lb.	38,500 lb.

III. Pipe Covering Facilities at Individual Shipyards

U. S. Navy Yard A.

There were 84 men working in the shop and 467 men on board ship. The shop was divided into two rooms, one of which was primarily for storage and occasional grinding and band saw cutting operations. The only mechanical exhaust ventilation in the shop was provided for the grinding, mixing and band saw cutting operations and was inadequate. In the other room layout, cutting and sewing were done with a small amount of space for storage. Cross draft ventilation was provided by open windows on both sides of the room.

Work on board ship was not supplied with exhaust ventilation.

No asbestos workers were found wearing respirators.

U. S. Navy Yard B.

There were 50 men working in the shop and 700 men on board ship. The shop was divided into four main rooms: Layout, Sewing, Cement, and Storage and Band saw combined. With the exception of the Cement Room, the doors between these were normally left open.

The work in the Sewing Room consisted mostly of fabricating and sewing valve boots and jackets. All the cement used on board ship was mixed in the Cement Room. There was no exhaust ventilation for either the Sewing or Cement Room. The band saw was equipped with a flexible exhaust tube above the table and an exhaust around the blade below the saw table. The layout table was equipped with exhaust ventilation as described above. There was no exhaust ventilation supplied on board ship for pipe covering and no workers were found wearing respirators.

Contract Yard C.

There were 51 men working in the shop and 123 on board ship. Layout, cutting and cement

mixing were done at one end of the shop. Dust respirators were occasionally worn during these procedures. At the other end of the shop the fabrication of boots, jackets and molds were carried out. A small amount of such fabrication was done on board ship.

Material was cut with a band saw in a separate room and the operator wore an approved dust respirator. The dust from this saw was exhausted through a slot under the table which caught only a part of the dust given off above the table.

There was no exhaust ventilation in the shop, other than for the band saw, and none for the pipe covering operations on board ship. All floors, walls and rafters of the shop were cleaned at frequent intervals with an industrial vacuum cleaner. Most pipe covering on board ship was applied in the evening during the second shift.

Contract Yard D.

There were 8 men in the shop and 160 men working on board ship. Pipe covering operations were done in two shops. In the main one, boots and jackets for pipe valves and connections were fabricated and surplus material stored. In the smaller shop the operations consisted of layout and cutting of amosite, water repellent amosite and fire felt. There was no exhaust ventilation in either shop nor for the pipe covering operation on board ship. All the asbestos cement was mixed in a compartment on board ship. The only worker who wore an approved dust respirator was the man who cut the two types of amosite. There was no band saw cutting of asbestos in this yard.

IV. Analyses of Settled Dust and Dust Counts

There are no established figures for permissible or safe dustiness in pipe covering operations. Dreessen et al. (2) in their study of asbestosis in the asbestos textile industry suggested 5 million particles of total dust by impinger as a threshold for that industry. We should like to point out that the asbestos textile and asbestos pipe covering industries differ widely in their dust exposures. In textile plants workers usually continue at specific jobs with fairly constant dust exposures for some years, whereas the pipe coverer may rotate between shop and ship and from small to large ship compartments with a wide variation in dust exposure.

In contrast to the textile worker, the pipe coverer's materials differ markedly in their asbestos content, ranging from 85 per cent magnesia (10–15% asbestos) to amosite (95% asbestos). When asbestos cements contain large amounts of diatomaceous earth there is a resultant silicosis hazard as indicated above.

In general we feel that dust counts below 5 million particles per cubic foot by Konimeter indicate good dust control.

Our figures in Table 2 were determined by the Konimeter and not with the impinger instrument. We used the Konimeter because it is light, easily portable and takes records which can be kept indefinitely. As is indicated in Table 3, the dustiest operations are band saw cutting, cement mixing, and installation on board ship.

V. Medical Findings

The incidence of asbestosis among pipe coverers as determined by chest X-ray is given in Table 4. The relation between years of exposure and per cent asbestosis is included in Table 5.

Due to frequent turnover of shipyard workers and the length of time required to X-ray a large number of workers, the number X-rayed may not equal the number of pipe coverers. At Contract Yard C X-rays were examined of men who had left the yard while at Navy Yard B a few pipe coverers were not X-rayed. At Navy Yard A the 48 X-rayed out of 551 were all older men working in the shop.

Some of these pipe coverers had had pre-shipyard experience in the asbestos industry, but the tables are based solely on shipyard exposure. At Contract Yard C, for example, the Asbestos Shop estimated that about one-third of their pipe coverers had worked with asbestos before coming to the yard.

The one case of advanced asbestosis at Contract Yard C had worked in the asbestos industry for 23 years before coming to work in the yard. At Contract Yard D the two cases of moderate asbestosis had worked 22 years and 30 years at pipe covering in their yard.

All of the X-ray films used in the above data were first read by roentgenologists of the Medical Department of the yard and then by one of the authors (W. E. F.). Dr. W. C. Dreessen, U. S. P. H. S., was kind enough to examine the three positive plates and he agreed on the diagnosis.

Since only three workers out of the 1074 X-rayed had asbestosis, and each of the three had been a pipe coverer for more than 20 years, it would

TABLE 2

ANALYSES OF SETTLED DUST AND AIR SAMPLES

OPERATION	PER CENT LESS THAN 10 MICRONS BY COUNT	ASBESTOS (BELOW 200 MICRONS)	PER CENT LESS THAN 10 MICRONS BY COUNT						DUST COUNTS (MPPCF)*					
			Diatomaceous earth	Serpentine	Other fibers (organic & glass)	Iron oxide (opaque)	Carbonates and oxides	Others	Number of samples	Total dust		ASBESTOS DUST		PER CENT ASBESTOS (range)
										Range of counts	Average	Range of counts	Average	
Layout and cutting														
Navy Yard A	95	16	6	12	6	24	26	10	2	3.5– 8.7	6.1	0.21–0.50	0.35	5.7– 6.0
Navy Yard B	98	10	8	12	tr	40	18	12	7	1.6– 6.5	4.2	0.01–0.54	0.23	0.6– 7.9
Contract Yard C	95	30	5	10	tr	26	14	15	4	17.1– 25.2	20.5	1.13–4.30	2.18	6.6–19.5
Contract Yard D	95	26	6	8	tr	29	21	10	5	6.5– 16.5	10.9	0.09–1.16	0.63	1.4– 8.7
Cutting with band saw														
Navy Yard A									2	11.0– 19.2	15.1	0.10–0.14	0.12	0.7– 0.9
Navy Yard B	98	9	7	8	tr	48	16	12	2	32.4– 46.6	39.5	2.8– 3.2	3.0	6.5– 8.7
Contract Yard C	98	9	63	2	tr	10	4	12	3	18.2–100+	73+	.9–12.8	6.19	4.3–12.8
Molding operations														
Contract Yard C	98	8	66	3	tr	7	6	10						
Contract Yard D	95	4	9	7	tr	48	10	12						
Sewing & prep. of boots & jackets														
Navy Yard A									2	3.5– 6.1	4.6	.01– .06	0.03	0.3 –1.0
Navy Yard B (Sewing asbestos cloth)	98	12	tr	9	tr	42	21	16	3	3.3– 6.0	6.8	0.0– 9.4	0.1	0. –6.4
(Stuffing with amosite)	98	8	8	11	tr	38	20	15	1	2.1–	2.1	0.	0.3	0.
Contract Yard C	95	26	6	11	3	28	12	14	2	10.6– 12.3	11.4	.45– .79	.62	3.7 –7.4
Contract Yard D	98	6	6	8	tr	38	28	14	5	3.9– 10.9	6.0	0. – .05	.03	0. –0.5
Storeroom														
Contract Yard D	95	15	8	7	tr	26	32	12						
Cement mixing														
Navy Yard A									16	5.4– 30+	31+	0. –0.52	0.2	0. – 0.7
Navy Yard B									2	67. –100+	84+	1.6 –1.7	1.7	1.4– 2.5
Contract Yard C									2	33.8– 48.7	41.3	1.6 –4.7	3.1	4.7–10.0
Contract Yard D (on board ship)									5	19.6– 40.0	32	0. – .02	.01	0. – .001
Grinding scrap materials														
Navy Yard A	88	8	20	16	1	10	33	12	15	9.4–100+	50+	0. –1.6	.47	0. –2.6
General room														
Navy Yard A									49	0.2– 24.6	10.0	0. –1.4	0.08	.02–0.3
Navy Yard B									2	1.6– 3.3	2.4	0. – .01	.01	0. –0.6
Contract Yard C									4	0.0– 21.6	14.2	0.34–1.7	.8	3.8 –7.9
Contract Yard D									5	3.9– 10.9	6.0	0. – .05	.02	0. –0.5
Aboard ship														
Navy Yard A									30	65. –250.	142	0. –0.17	0.02	0. –0.05
Navy Yard B									15	84.4–192.0	128	1.36–5.21	2.8	1.1 –3.7
Contract Yard C									15	25.3– 89.0	49.2	0.23–2.38	1.10	0.5 –6.8
Contract Yard D									15	8.0– 22.1	11.0	0. –0.21	0.03	0. –1.0

* *Note:* MPPCF = Million particles of dust per cubic foot of air.

TABLE 3

COMPARISON OF DUSTINESS OF VARIOUS OPERATIONS IN EACH SHIPYARD

OPERATION	NAVY YARD A		NAVY YARD B		CONTRACT YARD C		CONTRACT YARD D	
	Total dust	Asbestos dust	Total dust	Asbestos dust	Total dust	Asbestos dust	Total dust	Asbestos dust
	*MPPCF**		*MPPCF*		*MPPCF*		*MPPCF*	
Layout and cutting	6.1	0.35	4.2	0.23	20.5	2.18	10.9	0.63
Band saw cutting	15.1	0.12	39.5	3.0	73.0	6.19	—	
Sewing and fabrication	4.8	0.03	4.8	0.1	11.4	0.62	6.0	0.03
Cement mixing	31.0	0.2	84.0	1.7	41.3	3.1	32.0	0.01
Grinding	50.0	0.47	—		—		—	
General room	10.0	0.08	2.4	0.01	14.2	0.8	6.0	0.02
Shop average	30.0	0.25	26.9	1.0	32.0	2.6	7.6	0.23
Ship average	142.0	0.02	128.0	2.8	49.2	1.1	11.0	0.03

* *Note:* MPPCF = Million particles of dust per cubic foot of air.

TABLE 4

INCIDENCE OF ASBESTOSIS AMONG PIPE COVERERS

SHIPYARD	NUMBER OF PIPE COVERERS	NUMBER X-RAYED	NUMBER OF CASES OF ASBESTOSIS		
			Minimal	Moderate	Advanced
Navy Yard A	551	48	0	0	0
Navy Yard B	750	662	0	0	0
Contract Yard C	174	196	0	0	1
Contract Yard D	168	168	0	2	0
Totals	1683	1074	0	2	1

TABLE 5

RELATIONSHIP BETWEEN LENGTH OF EXPOSURE AND INCIDENCE OF ASBESTOSIS

SHIPYARD		YEARS IN PIPE COVERING INDUSTRY			
		0–2	2–5	5–10	10 plus
Navy Yard A	Exposed	26	13	8	3
	Affected	0	0	0	0
	Percentage	0%	0%	0%	0%
Navy Yard B	Exposed	225	435	67	22
	Affected	0	0	0	0
	Percentage	0%	0%	0%	0%
Contract Yard C	Exposed	0	105	45	17
	Affected	0	0	0	1
	Percentage	0%	0%	0%	6%
Contract Yard D	Exposed	26	118	5	9
	Affected	0	0	0	2
	Percentage	0%	0%	0%	22%

appear that asbestos pipe covering of naval vessels is a relatively safe occupation. However, it must be remembered that these men rotated among the various operations of pipe covering and were not continually exposed to high concentrations of asbestos dust as found in band saw cutting and cement mixing. The suggestions made relative to exhaust ventilation and respiratory protection are therefore of value in maintaining this low incidence of asbestosis.

DISCUSSION

The extremely low incidence of asbestosis found, 0.29 per cent, or 3 cases out of 1074 pipe coverers, stands in marked contrast to the high dust concentration found in several of the pipe covering operations. As shown in Table 3, the total dust concentration for band saw cutting ranged from 13.1 to 73.0 million particles per cubic feet, for cement mixing from 31.0 to 84.0, and for installation on board ship, from 11.0 to 142.0. The solution of this apparent discrepancy lies in a characteristic peculiar to the pipe covering trade, that is lack of a necessity for specialization. In general, pipe coverers are capable of doing all of the operations described above, and the worker may be changed from one operation to another or to different jobs in the same type of operation without loss of efficiency and according to the demands of ship construction. It is therefore apparent that a pipe coverer's environment may change every few days or few weeks at the most with a constant fluctuation in the dust concentration which he breathes. Therefore, the figures given in Table 3 for shop average and ship average cannot give a composite picture of the asbestos

dust that a worker may breathe over a period of years. It is further apparent that to obtain such a picture, daily dust counts at each specific job in each ship compartment and in the shop together with the time spent on each job would have to be compiled separately for each worker. In this respect, asbestos pipe covering differs markedly from the asbestos textile industry where dust concentrations for an operation do not fluctuate widely and where a worker will usually remain at a specific job for some years.

A further factor in maintaining a low incidence of asbestosis is that in band saw cutting, grinding, and cement mixing only one or two men are involved and the work is usually done at infrequent intervals such as several times a week.

Finally, pipe coverers also apply glass wool, rock wool, magnesia, and other types of non-asbestos insulation, all of which decreases the amount of exposure to asbestos dust. It seems likely to us that if the pipe coverers studied had worked steadily at any of the above operations where the amount of asbestos dust in the air was consistently high, the incidence of asbestosis among these workers would have been considerably greater. In view of the varied character of the environmental dust exposure in the pipe covering industry on naval vessels, it is manifestly impossible to set a threshold.

VI. Conclusions

1. The character of asbestos pipe covering industry on board naval vessels is such that conclusions drawn from other asbestos industries such as textiles, cannot be applied.

2. The operations of band saw cutting, grinding, cement mixing, and installation on board ship should be equipped with exhaust ventilation to keep the total dust concentration low.

3. The incidence of asbestosis among pipe coverers in the shipyards studied was low, 0.29 per cent or 3 cases out of 1074. In view of the nature of shipyard pipe covering work, this low incidence is not surprising.

4. Since each of the 3 cases of asbestosis had worked at asbestos pipe covering in shipyards for more than 20 years, it may be concluded that such pipe covering is not a dangerous occupation.

REFERENCES

(1) Lanza, A. J.: Silicosis and asbestosis. Oxford University Press, New York, New York, 1938.

(2) Dreessen, W. C. et al.: A study of asbestosis in the asbestos textile industry. Bull. No. 241, Public Health Service, U. S. Treasury Department, 1938.

(3) Fahey, J. C.: Ships and aircraft of the United States Fleet. 2nd War Edition, 1944. Published by Ships and Aircraft, 1265 Broadway, New York, New York.